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User Preferred Fire Extinguishing Agent for Cargo Compartments

July 1996

Final Report

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16. Abstract

The results of the survey sent to airlines and airframe manufacturers on User Preferred Fire Extinguishing Agent for Cargo Compartments are compiled in this report.

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PREFACE

This document was prepared by the Task Group "User Preferred Agents for Cargo Compartments" of the International Halon Replacement Working Group. The following participated in the Group.

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EXECUTIVE SUMMARY

The aviation industry unanimously desires that a halon replacement fire suppression system must be highly efficient, require none to minimal clean up effort, be low in toxicity to humans and animals, be environmentally friendly, be compatible with onboard systems, and lend itself to simple integration with existing systems at a reasonable cost.

The response to a survey mailed to end users was poor due to the lack of fire suppression effectiveness data for potential fire threats in cargo compartments. Approximately 46 percent of the users did not respond. A majority (60 percent) of the respondents believe the halocarbon group is the best choice, but a small but significant number believe water and particulate aerosols can better serve the purpose, figure 1. There was no solidarity of opinion on what agent group can best meet the above stated characteristics. However, the respondents were unanimous in their opinion that the high expansion foams are not appropriate for use in cargo compartments.

The Task Group (see preface) makes the following recommendations: (i) only agent and agent groups that meet the above stated characteristics should be considered; (ii) halocarbon and halocarbon blends, approved by the US Environmental Protection Agency (EPA) and recognized by the National Fire Protection Association (NFPA), be challenged with test fires to determine design parameters; (iii) aerosol agents and water additives which have been determined by this Task Group to be noncorrosive, people and animal friendly, and easy to clean be tested; (iv) high expansion foams be deleted from further consideration; (v) design parameters be developed for water-based system; (vi) a second survey be conducted when fire suppression data, gained from a series of fire tests, is available; and (vii) a copy of this report, without the appendices, be provided to all organizations participating in the survey.

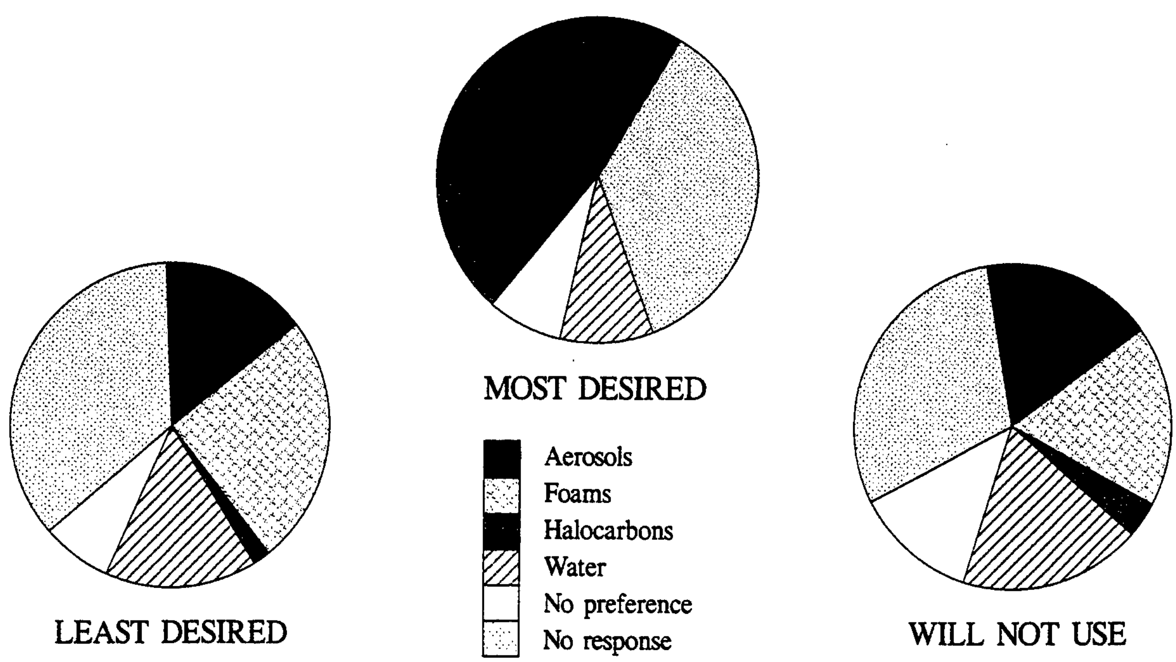

FIGURE 1. USER PREFERENCES

1. INTRODUCTION.

The International Halon Replacement Working Group (IHRWG) at its meeting, held 19-20 April 1995 in Rome, Italy, formed a Task Group to determine the aviation industry's preferred fire extinguishing agent(s) for use in cargo compartments. The Group felt this would help the regulatory authorities plan research activities to serve the aviation industry in an increasingly effective manner.

The Task Group prepared a survey using information contained in the report "Chemical Options to Halons for Aircraft Use," (reference 1), previously prepared by a Task Group of the IHRWG. The transmittal letter, survey information, and questionnaire, appendix A, were mailed to airframe manufacturers, airline operators, and associations representing airline operators and airframe manufacturers, reference appendix B. Thirty-nine questionnaires were returned (table 4).

The survey encouraged all recipients to submit written data, views, or arguments on fire extinguishing agents(s) that they would (or would not) use for fire suppression in cargo compartments. The survey emphasized that a choice of no preference was a valid response, and this information was of value. The survey stated that the Task Group would be obligated to assume a response of no preference if comments are not received by the given due date.

2. SURVEY RESPONSES.

The questionnaire (see appendix A) consisted of five questions, A through E.

Question A dealt with the agent groups. It requested that the four identified agent groups (particulate aerosols [A], high expansion foams [F], halocarbons [HC], and water and water-based [W] agents) be listed in order of preference and the degree of preference be indicated by a numerical rating; 0 being undesired and 10 being most desired. Part B requested that the preferred agent(s) be identified with reasons therefore.

Table 1 summarizes the responses to questions contained in appendix A. The desired and least desired agent groups are listed in tables 2 and 3.

Refer to table 1, the respondents indicated that the desired agent must have the following characteristics.

- High level of fire suppression efficiency (low agent weight and volume)
- Simple integration with existing system at a reasonable cost (close to drop-in)
- Clean agent (zero to minimal cleanup required after inadvertent discharge)
- Low impact on operations (training costs)
- Low toxicity to humans and animals
- Low environmental impact
- compatibility with existing fire detection systems

TABLE 1. RESPONSES TO QUESTIONS A AND B (SHEET 1 OF 5)

Question A: Four agent groups (particulate aerosols [A], high-expansion foams [F], halocarbons [HC], and water and water-based [W] agents have been identified suitable for fire suppression in cargo compartments. Please list in order of preference and assign rating: 0 = undesired, 10 = most desired

Question B: Please (i) identify the agent (or agents) that you prefer and (ii) tell us your reasons.

ORGANIZATION	RESPONSE	COMMENT
Aer Lingus PLC	A-5, F-0, HC-10, W-5	HC option appears to have optimum level of efficiency and ease of integration into existing system at a reasonable cost.
Aeroflot Airlines	No preference	
Aerospatiale	A-5, F-3, HC-10, W-5	HC: No design issues predicted, efficient and clean.
Airbus Industrie	A-5, F-3, HC-10, W-5	Close to a drop-in solution; retrofitable with low expense.
Air Canada	No preference	Default
Air China	No preference	Default
Air Creebec Inc.	A-5, F-0, HC-3, W-0	More information needed about aerosol before final decision.
Air Espana S.A.	No preference	Default
Air Europa	No preference	
Air France	A-8, F-3, HC-6, W-5	High efficiency, low volume and weight, simple design.
Air Transat	A-6, F-4, HC-5, W-3	Particulate aerosol: low weight
Alaska Airlines	No preference	A drop-in would be preferred.
Alitalia S.P.A.	A-0, F-1, HC-10, W-1	HFC-227ea is best with zero ODP and lowest weight and volume equivalent.
All Nippon Airways	No preference	Default
ALM Antillean Airlines	No preference	Default
Aloha Airlines	A-0, F-0, HC-10, W-0	Lesser weight penalty, clean agent, no cleanup required.

TABLE 1. RESPONSES TO QUESTIONS A AND B (SHEET 2 OF 5)

Question A: Four agent groups (particulate aerosols [A], high-expansion foams [F], halocarbons [HC], and water and water-based [W] agents have been identified suitable for fire suppression in cargo compartments. Please list in order of preference and assign rating: 0 = undesired, 10 = most desired

Question B: Please (i) identify the agent (or agents) that you prefer and (ii) tell us your reasons.

ORGANIZATION	RESPONSE	COMMENT
America West Airlines	No preference	Default
American Airlines	A-0, F-0, HC-10, W-9	HC: Less modification/testing. Water-environmental considerations.
American Trans Air	A-2, F-0, HC-8, W-10	Cost; ease of handling; cleanup after use (practically negligible).
Asiana Airlines	No preference	Default
Boeing	A-5, F-1, HC-10, W-2	HFC-227ea closer to Halon 1301 (wt and vol.), FC 3-1-10 low design concentration. HFC236fa—preliminary data looks good
British Airways	A-1, F-0, HC-10, W-0	Efficient, life, weight, training, costs.
Canadian Airlines	A-2, F-*, HC-10, W-8	Prefer HC of high efficiency, low toxicity and residue, e.g., HFC-227ea, *insufficient information provided.
Cathay Pacific	No preference	Default
China Airlines	No preference	No comments provided
China Eastern Airlines	No preference	Default
Continental Airlines	No preference	Default
Delta Airlines	A-2, F-3, HC-4, W-1	HC: Minimum aircraft modification and cleanup.
Deutsche BA	No preference	Default
Douglas Aircraft	A-8, F-5, HC-10, W-0	Halocarbon and aerosols—compatibility to existing systems. Least design impact.
Egyptair	No preference	Default
El Al Israel Airlines	No preference	No comments provided

TABLE 1. RESPONSES TO QUESTIONS A AND B (SHEET 3 OF 5)

Question A: Four agent groups (particulate aerosols [A], high-expansion foams [F], halocarbons [HC], and water and water-based [W] agents have been identified suitable for fire suppression in cargo compartments. Please list in order of preference and assign rating: 0 = undesired, 10 = most desired

Question B: Please (i) identify the agent (or agents) that you prefer and (ii) tell us your reasons.

ORGANIZATION	RESPONSE	COMMENT
Finnair	No preference	Default
Fokker Aircraft B.V.	A-6, F-4, HC-10, W-5	Clean agent advantage inadvertent discharge. Weight is lower for small airplanes.
Hawaiian Airlines	A-0, F-0, HC-10, W-6	No cleanup, total flood, less cost.
Iberia Airlines	No preference	Default
Indian Airlines		Facsimile not legible, requested resend.
Japan Airlines	A-4, F-0, HC-10, W-4	Weight and similarity to existing system agent.
KLM	A-6, F-4, HC-7, W-6	Effectiveness, clean agent, integration existing fire detection systems.
Korean Airlines	No preference	Default
Lockheed Martin	A-0, F-0, HC-10, W-5	Can knock down fire. No cleanup
Lufthansa	A-5, F-4, HC-10, W-1	Simple total flood system, no contamination, ETOPS, low modification costs.
NW Territorial Airways	No preference	Default
Olympic Airways	No preference	Default
Philippine Airlines	A-5, F-0, HC-6, W-10	Environmentally friendly, not hazardous, easy to clean

TABLE 1. RESPONSES TO QUESTIONS A AND B (SHEET 4 OF 5)

Question A: Four agent groups (particulate aerosols [A], high-expansion foams [F], halocarbons [HC], and water and water-based [W] agents have been identified suitable for fire suppression in cargo compartments. Please list in order of preference and assign rating: 0 = undesired, 10 = most desired

Question B: Please (i) identify the agent (or agents) that you prefer and (ii) tell us your reasons.

ORGANIZATION	RESPONSE	COMMENT
Qantas Airways	A-0, F-0, HC-5, W-0	HC offers the most promise. Nontoxic alternative to FIC-1311
	A-3, F-0, HC-10, W-5	Similar to halon system
Raytheon Aircraft (Beech)	A-7, F-5, HC-3, W-1	HFC 125: Close halon simulant
Sabena	No rating provided	HC for existing aircraft if recycled halon unavailable. W: for future aircraft—more friendly to humans and animals.
Saudi Arabian Airlines	A-4, F-3, HC-0, W-6	W: effective on both Class A and B fires. Onboard water can be used to supplement agent. Performance can be improved by additives, easy to maintain.
Scandinavian Airlines	A-2, F-5, HC-6, W-8	Harmless, effective.
Singapore Airlines	A-2, F-2, HC-10, W-3	HC: Drop-replacement. Don't want to replace or modify existing system.
South African Airways	A-2, F-4, HC-10, W-8	HC: Low environmental impact, very effective. Water: Very low environmental impact.
Southwest Airlines	A-0, F-0, HC-5, W-5	HC: Most like current system, least impact on operations.
Swissair	No preference	HC, A, F and W in order of preference, no ratings. HFC 227 ea or HFC 125. No cleanup, long suppression, no damage, good survival for chance animals.
Trans World Airlines	No preference	Default
United Airlines	No preference	Default

TABLE 1. RESPONSES TO QUESTIONS A AND B (SHEET 5 OF 5)

Question A: Four agent groups (particulate aerosols [A], high-expansion foams [F], halocarbons [HC], and water and water-based [W] agents have been identified suitable for fire suppression in cargo compartments. Please list in order of preference and assign rating: 0 = undesired, 10 = most desired

Question B: Please (i) identify the agent (or agents) that you prefer and (ii) tell us your reasons.

ORGANIZATION	RESPONSE	COMMENT
United Arab Emirates	A-9, F-6, HC-7, W-6	Five times more efficient than HC, easy installation, maintenance
USAir	No preference	Default
Varig	No preference	Default
Virgin Atlantic Airways	No preference	Default
AIA ATA ICAO IATA		Little time for response. Airlines rely on systems and airframe designers to develop alternatives to the point of removing most of the guess work

A majority selected halocarbon and halocarbon blend group, as the desired agent group, table 2. Particulate aerosols and water and water-based agent groups were selected by essentially equal number of respondents and were the second choice. Four respondents expressed no preference and an additional 25 registered no preference by default. Most of the respondents did not identify a particular agent as the agent of choice: HFC-227ea, HFC-236fa, HFC-125, and FC3-1-10 were mentioned as agents of choice by a few respondents.

TABLE 2. " DESIRED" AGENT GROUPS

Desired Agent Group: Agent group assigned the highest numerical rating (or identified as the desired agent group). In the event of equal rating of more than one group, all groups are counted as equally desired.

DESIRED AGENT GROUP	NUMBER OF RESPONSES	RESPONDENTS
Particulate Aerosols	5	Air Creebec, Air France, Air Transat, Raytheon Aircraft, United Arab Emirates
Foam	0	
Halocarbon and Blends	23	Aer Lingus, Aerospatiale, Airbus Industrie, Alitalia, Aloha, American Airlines, Boeing, British Airways, Canadian Airlines, Delta Airlines, Douglas Aircraft, Fokker, Hawaiian, Japan, KLM, Lockheed Martin, Lufthansa, Qantas, Sabena
Water and Water-based	5	American Trans Air, Philippine, Saudi Arabian, Scandinavian, Southwest
No Preference	29	No preference indicated by Aeroflot, Air Europa, China Airlines, El Al Israel. Twenty-five no preferences by default responses.

Refer to table 3. High-expansion foam group was identified as the least desired group by 19 respondents. Particulate aerosols and water and water-based agent groups scored equally (11 respondents) in the undesired category. One respondent identified halocarbon agent group as undesired, four expressed no preference, and 25 registered no preference by default.

TABLE 3. "LEAST DESIRED" AGENT GROUPS

Least Desired Agent Group: Agent group assigned the lowest numerical rating (or identified as the least desired agent group). In the event of equal rating of more than one group, all groups are counted as equally desired.

LEAST DESIRED AGENT GROUP	NUMBER OF RESPONSES	RESPONDENTS
Particulate Aerosols	11	Alitalia, Aloha, American Airlines, Canadian Airlines, Hawaiian Lockheed Martin, Qantas, Scandinavian, Singapore, South African, Southwest
Foam	19	Aer Lingus, Airbus Industrie, Air Creebec, Air France, Aloha, American Airlines, American Trans Air, Boeing, British Airways, Fokker, Hawaiian, Japan Airlines, KLM, Lockheed Martin, Philippine, Qantas, Singapore, Southwest, United Arab Emirates
Halocarbon and Blends	1	Saudi Arabian Airlines
Water and Water-based	11	Air Creebec, Air Transat, Aloha, British Airways, Delta, Douglas Aircraft, Lufthansa, Qantas, Raytheon Aircraft, Swissair, United Arab Emirates
No Preference	29	No preference indicated by Aeroflot, Air Europa, China Airlines, El Al Israel. Twenty-five no preferences by default responses.

Question C requested identification of the agent(s) that would not be used and the reasons therefor. Table 4 summarizes the responses. The following characteristics were identified as the reasons for not using an agent or agent group.

- significant cleanup effort
- low fire suppression effectiveness on Class A fires
- complex and heavy system
- high cost
- temperature susceptibility
- corrosion potential
- respiratory problems with livestock, harmful to humans and animals.

TABLE 4. RESPONSES TO QUESTION C (SHEET 1 OF 3)

Question C: Please (i) identify the agent (or agents) that you would not use and (ii) tell us your reasons.

ORGANIZATION	AGENTS YOU WOULD NOT USE AND WHY
Aer Lingus PLC	None identified
Aeroflot Airlines	None identified
Aerospatiale	We will only recommend not to use an agent. Today we insist on an agent with zero ODP and GWP very small. Not to be questionable very soon.
Airbus Industrie	We will use what is requested by airlines
Air Creebec Inc.	Water and water based—weight and temperature susceptible. Foam—weight and temperature susceptible. Halocarbons and halocarbon blends—asphyxiation of animals.
Air Europa	None identified
Air France	Foam—extensive subsequent cleanup required.
Air Transat	Water—damage to equipment, corrosion, freezing.
Alaska Airlines	None identified
Alitalia S.P.A.	FIC-1311—high toxicity Water—potential damages to the load.
Aloha Airlines	Particulate Aerosols—not desirable in aircraft environment and little is known about it. Foam —requires substantial cleanup effort. Water and water-based—weight penalty
American Airlines	Aerosol and Foam—do not offer complete and continuous fire suppression of deep seated fire
American Trans Air	Foam—We presume high cost and cleanup expense after use.
Boeing	FIC-1311—design concentration higher than LOAEL and NOAEL. HFC-125 design concentration higher than NOAEL. Water—potential safety issue
British Airways	Foams—weight, efficiency, safety.

TABLE 4. RESPONSES TO QUESTION C (SHEET 2 OF 3)

Question C: Please (i) identify the agent (or agents) that you would not use and (ii) tell us your reasons.

ORGANIZATION	AGENTS YOU WOULD NOT USE AND WHY
Canadian Airlines	Aerosol—corrosive inorganic salts and potentially noxious by-products
China Airlines	None identified
Delta Airlines	Foams and aerosols—system complexity and cleanup Water—weight penalty and effects on electrical systems
Douglas Aircraft	Water and water based—lots of disadvantages, several issues to be resolved, see Boeing's report submitted to the FAA
El Al Israel Airlines	None identified
Fokker Aircraft B.V.	Water and Foam—cleaning of cargo and cargo compartment. Installation expected to be heavier relative to halocarbon
Hawaiian Airlines	Foams—extremely difficult to clean, more complex design and installation. Aerosol—cleanup difficulty, costly system installation
Japan Airlines	Water—can't be used against electrical fire. Aerosol—cleanup difficulty. Foams—lots of uncertain factors Foam—cleanup problems, effectiveness, complexity of system
KLM	cleanup problems, effectiveness, system complexity
Lockheed Martin	Particulate aerosols and foams—excessive aircraft cleanup required which is costly. Also, the compounds can be corrosive and may not be easily removed from faying surfaces of parts and structure. I have first hand knowledge of the corrosive effects of foam on aircraft structure and would not like to see it repeated.
Lufthansa Technik AG	Water and water based—moisture in electrical systems and cargo, fire fighting in sections only, complicated system with high maintenance cost, excessive tubing and valve system, high-modification costs when changed from halon to water.
Philippine Airlines	Halocarbons, particulate aerosols, expansion foams—maintenance required after use, hazardous, not environmentally friendly, effect of migration of agent to other compartments.

TABLE 4. RESPONSES TO QUESTION C (SHEET 3 OF 3)

Question C: Please (i) identify the agent (or agents) that you would not use and (ii) tell us your reasons.

ORGANIZATION	AGENTS YOU WOULD NOT USE AND WHY
Qantas Airways	Water base—secondary damage to systems. Aerosols and foams—insufficient data available on Class A fires and respiratory problems for livestock carriage. Plumbing (high expense) and cleanup.
Raytheon Aircraft (Beech)	Agents that substantially increase weight and volume and have significantly higher toxicity levels in comparison to halon.
Sabena	None identified
Saudi Arabian Airlines	Halocarbon—expands at temperatures greater than 70°F, discharge time greater than 10 seconds, need quantity twice as much as halon. This will double number of bottles and maintenance requirements
Scandinavian Airlines	Exothermic pyrotechnically generated aerosols. It adds to heat generation.
Singapore Airlines	We would not use toxic agents or agents which leave residues because we carry livestock and perishable goods.
South African Airways	Aerosol—cleanup required, possibility of corrosion due to trapped material, possibly harmful to animals
Southwest Airlines	Particulate aerosols for reasons described.
Swissair	Foam—I do not know any foam which is not extremely corrosive. Foam will not stay at fire, will be blown away from hot air. Water may be used but aircraft has to be designed to prevent malfunction (of some systems). Both water and foam will have freezing problems. Aircraft manufacturers will reject corrosion warranty if water/foam is used.
United Arab Emirates	Water and water base—heavy installation, unsuitable for electrical fires, corrosive properties of water-based compounds not defined. Requires protection against low temperatures, expensive installation.

Refer to table 5. High-expansion foam was identified by the largest number of respondents, 16, as the agent group that they would not use. Particulate aerosols and water and water-based agent groups were identified by an equal number of respondents, 13, as agent groups they would not use. Three respondents indicated that they would not use halocarbons. Ten respondents expressed no preference and 25 registered no preference by default.

Question D of the questionnaire dealt with the toxic effects of the neat agent on humans. It inquired if an agent not recommended for use in areas normally occupied by humans (i.e., an agent that may cause an inhospitable environment in the event of a massive leak or inadvertent discharge) would be acceptable for use. Table 6 summarizes the responses. Refer to table 7, a majority of the respondents, 21, stated they would not use such an agent. Five respondents answered with conditional "yes" and four with unconditional "yes". There were 31 no responses.

Part E of the questionnaire requested additional comments/suggestions. These are summarized in table 8.

TABLE 5. "WILL NOT USE" AGENT GROUPS

"Will Not Use" Agent Group(s). Agent group(s) identified by the respondents that they would not use. In the event of several groups identified, all groups are counted.

"WILL NOT USE" AGENT GROUP	NUMBER OF RESPONSES	RESPONDENTS
Particulate Aerosols	13	Aloha, American Airlines, Canadian Airlines, Delta, Hawaiian, Japan, Lockheed Martin, Philippines, Qantas, Scandinavian, Singapore, South African, Southwest
Foam	16	Air Creebec, Air France, Aloha, American Airlines, American Trans Air, British Airways, Delta, Fokker, Hawaiian, Japan Airlines, KLM, Lockheed Martin, Philippine, Qantas, Singapore, Swissair
Halocarbon and Blends	3	Air Creebec, Philippine, Saudi Arabian Airlines
Water and Water-based	13	Air Creebec, Air Transat, Alitalia, Aloha, Boeing, Delta, Douglas Aircraft, Fokker, Japan Airlines, Lufthansa, Qantas, Swissair, United Arab Emirates
No Preference	35	Aer Lingus, Aeroflot, Aerospatiale, Airbus Industrie, Air Europa, Alaska, China Airlines, El Al Israel, Raytheon Aircraft, Sabena, and twenty-five organizations by default.

TABLE 6. RESPONSES TO QUESTION D (PAGE 1 OF 2)

Question D: Will you use an agent not recommended for use in areas normally occupied by humans? (i.e., an agent that may create an inhospitable environment for humans.

ORGANIZATION	AGENT THAT MAY CREATE AN INHOSPITABLE ENVIRONMENT FOR HUMANS—YES/NO
Aer Lingus PLC	No
Aeroflot Airlines	No response
Aerospatiale	No response. We will use what is requested by airlines.
Airbus Industrie	No response
Air Creebec Inc.	No. Unless it is allowable in limited quantities. Not recommended does not mean unusable
Air Europa	No response
Air France	Will not use and will not accept agent not recommended in area normally occupied by humans.
Air Transat	Yes
Alaska Airlines	No response
Alitalia S.P.A.	No
Aloha Airlines	No
American Airlines	No
American Trans Air	No
Boeing	No
British Airways	No
Canadian Airlines	No
China Airlines	No response
Delta Airlines	Yes
Douglas Aircraft	No

TABLE 6. RESPONSES TO QUESTION D (PAGE 2 OF 2)

Question D: Will you use an agent not recommended for use in areas normally occupied by humans? (i.e., an agent that may create an inhospitable environment for humans.

ORGANIZATION	AGENT THAT MAY CREATE AN INHOSPITABLE ENVIRONMENT FOR HUMANS—YES/NO
El Al Israel Airlines	No response
Fokker Aircraft B.V.	Yes—as long as the total installation complies with the toxicity requirements.
Hawaiian Airlines	Yes—toxicity levels must be minimal
Japan Airlines	No
KLM	Yes—if acceptable to authorities
Lockheed Martin	Yes—but only under strict control to assure people and animals won't be harmed by it.
Lufthansa Technik AG	No
Philippine Airlines	No
Qantas Airways	No
Raytheon Aircraft (Beech)	No
Sabena	No
Saudi Arabian Airlines	No
Scandinavian Airlines	Yes
Singapore Airlines	No
South African Airways	Yes
Southwest Airlines	No
Swissair	Yes—if the aircraft is designed such that no agent can enter the cabin area. Think also about animal transport. We need that business
United Arab Emirates	No

TABLE 7. WOULD YOU OR WOULD YOU NOT USE AN AGENT THAT MAY CREATE AN INHOSPITABLE ENVIRONMENT (REFERENCE QUESTION D)

YES OR NO	NUMBER OF RESPONSES	RESPONDENTS
Yes	9	Air Transat, Fokker, KLM, Lockheed Martin, and Swissair conditional yes. Delta, Hawaiian, Scandinavian, South African Airways.
No	21	Aer Lingus, Air Creebec, Air France, Alitalia, Aloha, American Airlines, American Trans Air, Boeing, British Airways, Canadian Airlines, Douglas Aircraft, Japan Airlines, KLM, Lufthansa, Philippine, Qantas, Raytheon Aircraft, Sabena, Saudi Arabian, Singapore, Southwest, United Arab Emirates
No response	31	Aeroflot, Aerospatiale, Airbus Industrie, Air Europa, Alaska, China Airlines, China Airlines, and twenty-five organizations by default

TABLE 8. COMMENTS AND SUGGESTIONS (SHEET 1 OF 2)

ORGANIZATION	COMMENTS AND SUGGESTIONS
Aer Lingus PLC	No comments
Aeroflot Airlines	No comment
Aerospatiale	No comments
Airbus Industrie	No comments
Air Creebec Inc.	All items referenced address cargo compartments of large aircraft. Nothing appears suitable to regional cargo aircraft in Combi mode. It appears more R&D is required to a type of extinguishing product.
Air Europa	No comments
Air France	Combi aircraft are not taken in consideration, approach may be different for full cargo aircraft.
Air Transat	R&D still required.
Alaska Airlines	A "drop-in" replacement would be preferred. This will minimize any hardware and operational revisions required. Also, any new agent used should not be harmful to aircraft structure or systems and preferably not harmful to human or animal life.
Alitalia S.P.A.	We would like an agent not requiring major modification on aircraft plants for old aircraft.
Aloha Airlines	No comments
American Trans Air	Cost of retrofit must be considered. Implementation time for the new system must be ample for operators.
Boeing	Halocarbons best for immediate use. Research for agents to reduce weight and volume.
British Airways	No comment
China Airlines	No comments
Delta Airlines	No comments
Douglas Aircraft	No
El Al Israel Airlines	No comments
Fokker Aircraft B.V.	Yes—as long as the total installation complies with the toxicity requirements.

TABLE 8. COMMENTS AND SUGGESTIONS (SHEET 2 OF 2)

ORGANIZATION	COMMENTS AND SUGGESTIONS
Hawaiian Airlines	The toxicity level in cargo compartment must be minimal
Japan Airlines	Select agent based on (i) safe for human and nature, (ii) easy to clean, (iii) good availability, and (iv) consistent with other agents in aircraft
KLM	More detailed information is required with regard to halocarbon and aerosols to express a more motivated preference for the four agent groups. The response is a preliminary indication which agent is preferred.
Lockheed Martin	Halon is the best one
Lufthansa Technik AG	We prefer to have one agent. Agents in all four systems (cargo, engine, handheld, and waste bin), but if that is not possible, a slightly toxic agent (like 1211) would be accepted.
Philippine Airlines	No comment
Qantas Airways	Would not use any fire suppressant unless material equals or exceeds existing halon performance criteria and meets nontoxicity requirements.
Raytheon Aircraft (Beech)	No comments
Sabena	No comments
Saudi Arabian Airlines	Less information available about (1) particulate and (2) foams. More details will help in evaluation
Scandinavian Airlines	Cleanup after a discharge should be considered a minor problem compared to an uncontained fire. Has the technique suggested for fuel tanks using inert gas or exhaust gas been considered, e.g., as a follow-up to initial fire suppression with water mist.
Singapore Airlines	We want a drop-in for Halon 1301 that requires little or no modification to our existing systems.
South African Airways	What about the use of carbon dioxide.
Southwest Airlines	Keep looking for an acceptable substitute for halon.
Swissair	No comment
United Arab Emirates	Task force should establish capability of particulate aerosol against Class A fires. Chances of a Class A fire originating in cargo compartment is more that a Class B.

3. DATA ANALYSIS.

The survey data can be analyzed either including or excluding the default responses.

3.1 RESPONDENT DATA ONLY (EXCLUDING DEFAULT RESPONSES).

If one excludes no preference and default responses, the following is evident

• Most desired agent group	Halocarbon and halocarbon blends
• Least desired agent group	High-expansion foams
• Agent group will not use	High-expansion foams
• Agent may create inhospitable environment	No

The preferred halocarbons identified, in order of preference are as follows:

(i) Heptafluoropropane (HFC-227ea), a product of Great Lakes Chemical and known by the trade name, FM200.

(ii) Pentafluoropropane (HFC-125), a product of DuPont and commonly referred to as FE-25, Hexafluoropropane (HFC-23FA), a product of DuPont and commonly referred to as FE-36, and Perfluorobutane (FC-3-1-10), a product of 3M and commonly referred to as CEA-410. (All of these agents are second preference.)

Based on NFPA heptane cup burner data, all the above agents would impose substantial weight and volume penalties. Actual penalties may be different (generally believed to be higher) than those indicated by heptane cup burner data due to agent leakage from the compartment, minimum agent concentration required to maintain a fire suppressed, or agent concentrations required to suppress cargo compartment peculiar threats (deep-seated) fire in a container fire and fire hazard due to aerosol cans). Presently test data for cargo compartment type fire threats are unavailable.

3.2 ALL DATA (INCLUDING DEFAULT RESPONSES).

If one accounts no preference and default responses, one reaches the following conclusions.

• Most desired agent group	No preference, halocarbons desired by respondents
• Least desired agent group	None identified, high-expansion foams least desired by respondents
• Agent group will not use	None identified, high-expansion foams identified by respondents
• Agent may create inhospitable environment	No response, majority of respondents - No.

The above suggests that the majority of users are undecided. Majority of respondents prefer halocarbons because of their similarity with halon 1301, and dislike high-expansion foams because of corrosion potential and required cleanup effort. Some would use particulate aerosols because of their high effectiveness (Class B fires). Others would use water and water-based agents because they are inexpensive, compatible with humans and animals, environmentally friendly, and easy to handle. One respondent mentioned that cleanup effort after the use of water system is practically negligible. However, a majority expressed concern that the required cleanup for a water system would be substantial. some mentioned that they would not use particulate aerosols because of required cleanup effort potential corrosion, and exothermic reaction required to generate the aerosol. Also, some mentioned that they would not use water and water-based agents because of weight, corrosion, damage to equipment and cargo, agent freezing possibilities, safety concerns, etc.

In summary, there is a lack of consensus on the agent group that the industry would use. However, there is a solidarity of opinion on the characteristics the agent/system must have to be acceptable: high level of fire suppression efficiency for the likely fire hazards, low toxicity (people and animal friendly), low environmental impact, minimal to nil clean up in the event of inadvertent discharge. For retrofit applications, the agent/system must require minimum change (a drop-in agent is preferred) and must have minimum impact on operations, training and other onboard (e.g., fire detection) systems. Dislike for foams appears to be unanimous amount the respondents.

4. RECOMMENDATIONS.

The Task Group recommends the following.

i. Only agent and agent groups that meet "desired" characteristics (see paragraph 2)) be considered for cargo compartments. This is the industry consensus.

ii. Halocarbons and water be challenged with the test fires, and deign parameters (volumetric concentration for total flood or weight per unit area for zonal applications) be determined for acceptable level of protection. The data should allow the (rough order of magnitude) determination of agent weight for protection up to 180 minutes. This is recommended for industry to evaluate weight, volume, and cost impacts for (i) airplanes scheduled for major refurbishment (expected life 12 years or greater) and (ii) new aircraft.

   Halocarbons and halocarbon blends recognized by NFPA be tested in the manner (total flood, streaming, misting, etc.) recommended by agent manufacturer to obtain comparative data for the various agents. This is recommended because agent concentration required for fire suppression depends on the threat (Class of fire, preburn time, degree of suppression, etc.). This data are essential for selection of the best halocarbon for intended use.

iii. A Task Group should be formed to evaluate characteristics of agents belonging to the particulate group and additives that enhance fire suppression effectiveness of water. The

should be subjected to large scale (FAA) tests only when the following has been accepted by the users.

a The agent/additive is noncorrosive to materials of construction of cargo compartments.

b. The agent/additive is people and animal friendly.

c. The agent/additive can be cleaned with minimal effort.

In addition, the agent/additive must be recognized by NFPA as a fire suppression agent.

iv. High-expansion foams be deleted from further consideration. Unanimity exists in the industry against the use of this group of agents.

v. Water (potable) be challenged with test fires to establish design parameters (rough order of magnitude) for a water-based system which provides the desired level (equivalent to that of Halon 1301) of protection. Potable water is readily available in large quantities and conduct of these tests (while waiting for the delivery of halocarbon agents) is recommended to minimize program delays. The tests are also recommended for the following reasons:

a. They will result in refinement of the test protocol and maintenance of test facilities and personnel in a peak state of preparedness. This would facilitate halocarbon agent tests when the agents are available.

b. It is being proactive.

c. The data may provide a base for evaluating other types of fire suppression systems for new airplanes

d. Rules and regulations applicable to the use of halocarbons [Environmental—allowable global warming potential, atmospheric life time and safety—low observed adverse effect level, no observed adverse effect level] are in an unsettled state. Water-based fire suppression system (with design features to preclude undesired characteristics) may provide an option in the event restrictions on the production or use of halocarbons are imposed.

vi. On completion of recommendations i through v a second survey be conducted with fire suppression data gained from a series of fire tests. The Task Group recommends:

a. Coaxing of the users by the FAA and other regulatory agencies to respond to the survey. The respondents be requested to return the questionnaire to the FAA or their regulatory agency as this would impart greater significance to the survey.

b. The next questionnaire be divided into two parts:

Part A—In-service airplanes scheduled for major refurbishment (expected life 12 years or greater).

Part B—New airplanes.

We suggest that the questionnaire clarify that the intent of the IHRWG is to develop the best fire suppression system(s) for refurbished and new airplanes.

5. REFERENCES.

1. Robert Tapscott, et al., Chemical Options to Halons for Aircraft Use, Task Group 6 of the International Halon Replacement Working Group, Report DOT/FAA/CT-95/9, February 1995.

APPENDIX A—TRANSMITTAL LETTER, SURVEY INFORMATION AND QUESTIONNAIRE

U.S. Department of Transportation

Federal Aviation Administration

Technical Center

Atlantic City Int'l Airport
New Jersey 08405

June 5, 1996

Dear Mr.

The enclosed survey has been prepared by a task group representing airlines and airframe manufacturers on the subject of replacement agents for Halon 1301 in cargo compartments.

As you are aware, halon is a chlorofluorocarbon and has been banned from production since January 1, 1994. Research is ongoing to find a suitable replacement agent or system for aircraft use. It would be useful for the research efforts if the types of agents/systems that airlines/airframe manufacturers would or would not use were known. Your responses will help research efforts to find a viable replacement for halon.

Please send your responses to Mr. Alankar Gupta of Boeing Commercial Airplane Group by July 12, 1996. His address and fax number are listed below:

Mr. Alankar Gupta
Mail Stop: 6H-TR
Boeing Commercial Airplane Group
PO Box 3707
Seattle, WA 98124
Fax: 206-237-9444

Mr. Gupta will tabulate the responses in order to provide a list of viable options to be researched further.

Sincerely yours,

Richard G. Hill
Program Manager
Fire Safety Section

Enclosure

USER PREFERRED FIRE EXTINGUISHING AGENT FOR CARGO COMPARTMENTS

ORGANIZATION: International Halon Replacement Working Group
Task Group: User Preferred Agents for Cargo Compartments

SUMMARY: This survey requests information from the user community on fire extinguishing agent(s) that would or would not be considered for use in cargo compartment fire suppression systems. This information is requested to help guide the regulatory authorities (FAA and JAA) develop airworthiness criteria fro the evaluation on non halon fire suppression agents/systems.

DATES: Comments must be received by July 12, 1995.

ADDRESS: Alankar Gupta, Chairman
Task Group User Preferred Agents - Cargo Compartments
Mail Stop 6H-TR
Boeing Commercial Airplane Group,
P.O. Box 3707, Seattle, WA 98124 (USA)
FAX 206-237-5444

FOR FURTHER INFORMATION CONTACT:

NAME	ORGANIZATION	PHONE NUMBER	FAX NUMBER
Jelle Benedictus	KLM (The Netherlands)	31-20-64-906-31	31-20-64-881-62
John Blackburn	Avro International Aerospace (England)	061-439-5050 x3696	061-767-3180
Bernd Dunker	Deutsche Aerospace Airbus (Germany)	040-7437-5309	040-7437-4742
Thomas Grabow	Daimler Benz Aerospace Airbus (Germany)	49-421-538-4033	49-421-538-4639
Alankar Gupta	Boeing Commercial Airplane Group (USA)	206-237-7515	206-237-5444
Hans Humfeldt	Deutsche Lufthansa RG (Germany)	49-40-5070-2406	49-40-5070-2385
Jean Paillet	Aerospatiale (France)	33-61-93-71-65	33-61-93-88-74
Krijn Pellen	Fokker Aircraft B.V. (The Netherlands)	020-605-2069	020-605-2895
Marco Potschkat	Airbus Industrie (France)	33-61-93-37-59	33-61-93-49-08
Bud Roduta	United Airlines-SFOCE (USA)	415-634-4857	415-634-4986
Felix Stossel	Swissair (Switzerland)	41-1-812-6930	41-1-812-9098
John O'Sullivan	British Airways (UK)	44-81-562-5460	44-81-562-2928 or 2026
Sham Hariram	McDonnell Douglas Corporation (USA)	310-593-4305	310-593-7104

SUPPLEMENTARY INFORMATION: At the fifth meeting of the International Halon Replacement Working Group, held 19-20 April 1995 in Rome, Italy, a Task Group was formed to determine the aviation industry's preferred fire extinguishing agent(s) for use in cargo compartments. This information will serve to reduce the list of potential candidate agents and thus assist the regulatory authorities in planning their research activities to serve the aviation industry in an effective and timely manner.

Membership to this Task Group was limited to representatives from airframe manufacturers and airline operators. Persons identified above (paragraph "For Further Information Contact") volunteered to serve in the Group. The Group was tasked to:

(i) Contact users (airframe manufacturers and airline operators) and determine fire extinguishing agents they would and would not use for fire suppression in their cargo compartments.

(ii) Prepare a report for presentation at the Next IHRWG meeting, scheduled for July 18, 1995.

You are encouraged to submit written data, views or arguments (see questionnaire attached) on fire extinguishing agent(s) that you would (or would not) use for fire suppression in the cargo compartments. If you have no preference, this information is also of value and we request that you communicate this position. The Task Group shall be obligated to assume that you have no preferred agent if comments are not received by the due date of 12 July 1995.

Availability of Survey

Any person may obtain a copy of this survey by requesting it from any member of the Task Group. Refer to paragraph "For Further Information Contact" or from Ms. April Horner, IHRWG Coordinator, phone 609-485-4471, Fax 609-646-5229. By agreement of the IHRWG only written comments from airframe manufacturers and airline operators shall be considered.

Background

Given the phase out of halon production, (Montreal Protocol and US Clean Air Act) the Aerospace Industries Association (AIA) held an International Symposium - Halon Replacement in Aviation 9-10 February 1993. The symposium was attended by representatives from the Federal Aviation Administration (FAA). At this meeting it was concluded that:

(i) current regulations do not require the use of halon,
(ii) no regulatory action is necessary, and
(iii) fire hazards, test protocols, and performance criteria all need to be developed.

On June 17, 1993 the FAA published Notice 93-1 in the Federal Register inviting industry to join in a cooperative effort to develop test articles, conduct evaluation tests, develop minimum performance standards, and provide guidance in drafting certification/compliance documents.

This invitation resulted in the formation of the International Halon Replacement Working Group (IHRWG). Membership in the Group is open to all interested parties. The first meeting of the IHRWG was held on 13 October 1993, and the most recent, the fifth, was on 19-20 April, 1995.

Discussion of Cargo Compartment Fire Suppression

Fire protection requirements and characteristics of potential agents/systems (conceptual) is discussed in the next several sections.

Regulations

Federal Aviation Regulations and Joint Aviation Regulation FAR/JAR 25.857 require that Class C cargo compartments be provided with an approved built-in fire extinguishing system. The regulations do not mandate the use of any particular agent or system type.

FAR/FAR 25.851 applicable to the design of built-in fire extinguishing systems requires that the capacity of each required built-in extinguishing system must be adequate for any fire likely to occur in the compartment where used, considering the volume of the compartment and the ventilation rate.

Current Practice

Currently all aircraft cargo compartment built-in fire extinguishing systems use halon 130a as the fire extinguishing agent. All systems are "total flood" type. An initial minimum agent concentration of 5% by volume and subsequent minimum agent concentration of 3% by volume for the remainder of the flight has been accepted to meet the requirements of FAR/JAR 25.851. The concentrations are based on empty cargo compartment volume.

International Halon Replacement Working Group (IHRWG)

The goal of the IHRWG is to introduce non-halon fire suppression systems into service in a timely, cost effective manner, with no compromise in present level of safety. The group is working all areas of fire protection on board aircraft: engines and auxiliary power unit, cargo compartment, hand-held fire extinguishers for the occupied area, lavatory trash container, and dry bay (military). The IHRWG has formed several Task Groups to conduct detailed studies. Studies applicable to cargo compartment fire suppression that have been conducted are:

(i) Likely Fire Threats in Class C Cargo Compartments (Task Group 4), and

(ii) Chemical Options to Halons for Aircraft Use (Task Group 6), Published by FAA as DOT/FAA/CT-95/9.

The above reports are in public domain and are available from the FAA Technical Center, NJ. (Contact Ms. April Horner, at 609-485-4471, Fax 609-646-5229.)

Cargo Compartment Fire Suppression System Minimum Performance Standard

FAA/JAA have established that non-halon fire suppression system should provide the same level of protection (safety) as the present halon system. In particular, the systems must be capable of suppressing

(i) exposed or surface Class B (flammable fluids) fire,
(ii) deep seated Class A (carbon compounds) fire, and
(iii) prevent fire hazards of an aerosol can (pressurized flammable gas).

FAA/JAA have neither defined "standard" tests and nor what is implied by equivalent level of protection (safety). FAA/JAA position is that critical tests (fire scenarios) depend on the selected agent/system and equivalent level of protection (safety) can only be established by back-to-back tests using halon 1301. In short, the FAA/JAA will conduct the tests and define acceptable design parameters for the selected agent/system. It should be noted that the present halon 1301 system design parameters (acceptable halon concentrations) were previously established by FAA.

IHRWG Task Group 6 Report "Chemical Options to Halons for Aircraft Use"

At the April 19-20 meeting, Task Group 6 recommended that the FAA/JAA develop test protocols for the following classes of fire extinguishing agents for fire suppression in the cargo compartments:

(i) Water and water-based agents,
(ii) Halocarbon and halocarbon blends,
(iii) Particulate aerosols, and
(iv) High expansion foam.

There are several agents in each class and each agent has its pros and cons. Several members of IHRWG commented that they would or would not use certain agents in the cargo compartment. These remarks caused the IHRWG to form this Task Group. The Group has been tasked to determine why some fire extinguishing agent/system would or would not be used by the aviation industry. FAA/JAA believe this intelligence would help reduce potential candidates and help them plan their research and development effort such that they can effectively serve the aviation industry.

Potential Fire Extinguishing Agents/Systems

Potential fire extinguishing agents and conceptual systems are described. It should be noted that conceptual systems are included to help one understand how a particular agent may be used or the system may be integrated with existing on board systems. The conceptual systems are not recommendations.

Water and Water-Based Agent/System

Several investigators have determined that water in the form of mist or fog is an extremely effective fire suppression agent for Class B (flammable fluid) fires. Some claim its effectiveness is equal to or better than halon 1301. Water and water-based agents are highly effective in suppressing Class A fires (wood, cloth, paper, rubber, carbon compounds that form glowing embers, etc.). There are no environmental restrictions on the use of water and it is universally available at a very reasonable cost.

The FAA Technical Center conducted several tests using water mist/fog/spray and determined that it provides a level of protection (safety) equivalent to that provided by halon 1301 for a deep seated fire. The critical location of this fire threat, for this class of agent, is in a damaged container located next to the compartment bulkhead. The FAA used a zonal fire suppression system in which the suppression process was activated by temperature at the ceiling liner. Activation temperatures used were in the range of 200°F-250°F (93°C-121°C). The FAA presented test system (which used solenoid valves to cycle the system) and test results at the last IHRWG meeting. [No formal test report is presently available. A copy of the presentation may be requested from Ms. April Horner, phone 609-485-4471, Fax 609-646-5229].

Figure 1 shows a "conceptual system", developed by the Task Group, which can be made to perform the same function as the system tested by the FAA. The system consists of a normally unpressurized tank [1] filled with water or a water-based agent. The tank is connected to main supply ducts of the forward [2] and [3] cargo compartments. At the interface of each main supply duct/tank is located a normally closed pyrotechnically activated (or solenoid controlled) valve [21, 31]. The main supply duct is connected to zone supply ducts [A, B, C, D, E, F, G, H]. In each zone supply duct is installed a spring loaded or normally open valve [a, b, c, d, e, f, g, h] which is maintained closed by an alloy of low melting temperature (eutectic). The eutectic remains solid for temperatures less than TBD°F [TBD=200-250°F (93°C-121°C) or lower]. Down stream of the valve are located the fire suppression agent delivery nozzles. This conceptual system is similar to industrial sprinkler

The FAA tested the system in a test cargo compartment, approximately the size of a DC-10 airplane cargo compartment. It is probable that in the optimized system each fire suppression zone may be slightly bigger than the maximum size container or pallet that can be transported in the compartment. Also, it is reasonable to assume that the agent may allow the use of essentially similar size fire suppression zones and mist/fog nozzles in all wide body cargo compartments to maximize commonality of parts. Since, fire suppression in a maximum of two zones (fire at the boundary of two zones) would be required during any flight it is reasonable to conclude that the fire agent weight (or volume) would be independent of the cargo compartment size or volume. It may depend on the flight duration if the initial fire suppression effort is inadequate to suppress the life below its critical (self sustaining) heat release rate. It has been suggested that one may be able to extend suppression capability by utilizing on-board potable water after the "dedicated" agent has been used.

The agent is pressurized by one or more pressurizing sources. The pressurizing source may be bleed air, electric motor driven air compressor, compressed inert gas bottle(s) or gas generator(s). The selection of the pressurizing source and the number of sources would depend on a number of factors: system operation (single or multiple discharges), source availability, installation, failure analysis, etc., which are presently not known. The FAA in their test used multiple discharges (by opening/closing of the solenoid valves in the agent distribution system in response to temperature near the ceiling).

The fire suppression agent may be potable water, distilled water, ionized water, and may (or may not) contain additives. The additives, if added, may be used to (i) depress freezing point, (ii) modify surface tension (wetting agent), and/or (iii) enhance fire suppression effectiveness. The FAA did not use additives in their tests. Several manufacturers claim that additives (biodegradable, environmentally safe) can enhance fire suppression effectiveness and help reduce agent weight. The FAA used approximately 31 gallons (258 pounds or 177 kg) of water to maintain suppression of the test fire for 90 minutes.

The storage tank may be insulated to protect the agent from cold temperatures. Other features such as agent drain/fill, heating blanket, immersion heater, etc., may be incorporated to allow extended storage in subfreezing temperatures.

The system may be integrated with existing (smoke, ionization) fire detection systems. The system operating logic is shown on figure 1. When a fire alarm is annunciated in a compartment, the pilot arms the corresponding squib (21 or 31) by pushing the appropriate squib arm switch. This action reconfigures the air-conditioning/ventilation system and illuminates the ARMED legend on the switch plate. (These functions can also be caused to occur automatically on detection of fire). Pressing the discharge switch opens the appropriate main supply valve and initiates tank pressurization (gas generator, inert gas bottle, compressor or bleed air). On agent discharge (detected by drop in system pressure by a sensor not shown) the legend DISCH illuminates. In summary, it is feasible to design the system with crew actions and flight deck indications identical to the present halon 1301 system.

If the alarm is false or the fire does not produce adequate heat to melt the eutectic, the agent does not discharge. Thus, no clean-up is required in the event of a false alarm or a minor (non hazardous) fire. However, maintenance would be required to depressurize the system and recharge the pressurizing source (if expendable).

On discharge most of the agent will remain concentrated in and around the zone(s) in which it was discharged with some migration to other areas. Wetting of the cargo will occur and water damage (similar to damage one may experience in a heavy mist or drizzle) may occur. The agent will migrate to the bilge area. Migration of the agent to compartments occupied by crew and passengers and to equipment located outside the cargo compartment would depend on the integrity of the compartment liner. Means to exclude hazardous quantities of smoke, flames, or extinguishing agent, form any compartment occupied by the crew or passengers is a FAR/JAR 25.857 requirement and it is reasonable to assume that agent migration from a maintained compartment will be a minimum.

Water is non-toxic. Also, it does not substantially reduce oxygen partial pressure when released in an enclosed space. Its discharge would not cause asphyxiation of animals in the cargo compartment.

The agent storage tank(s) would be normally pressurized. Maintenance of the system may be simple and the required maintenance skill of a low level.

Halocarbon and Halocarbon Blend Agent/System

The conceptual halocarbon or halocarbon blend agent system would be similar to the present halon 1301 system, figure 2. Halocarbon is independently plumbed from two bottles to each of the cargo compartments. Each bottle is pressurized to a high pressure by an inert (nitrogen) gas. When fire is detected in either the forward or aft compartment, the corresponding squibs are armed by pushing the appropriate squib arm switch. This action arms both extinguisher bottle discharge switches and illuminates the ARMED legend on the switch plate. In addition it configures the air conditioning and ventilation system. (These functions can also be caused to occur automatically on detection of fire). Bottle 1 is discharged by pressing the 1-BTL discharge switch. On successful discharge, the legend DISCH illuminates. The first bottle provides TBD1% concentration of the agent to knock down the fire. The second bottle is discharged after a prescribed time interval (manually or automatically, either as a dump or a metered supply) to prevent the agent concentration from falling below TBD2% by volume. The system would be a total flood system. The extinguishing agent weight (or volume) would depend on cargo compartment size or volume, compartment leakage rate and flight duration.

Commercialized zero Ozone Depletion Potential (ODP) fire extinguishing agents and their characteristics are listed in table 1. Table 1 data is from IHRWG Task Group 6 report (DOT/FAA/CT-95-9 Chemical Options to Halons for Aircraft Use). Presently , there are no generally accepted standards on Global Warming Potential (GWP) and Atmospheric Life Time (ALT). From environment protection considerations lower value agents are preferred. The table 1 design concentrations are recommended for extinguishment of Class B fires with n-heptane fuel. These concentrations may be considered as initial dump concentration (TBD1%) required to knock down flames. The subsequent lower suppression concentration (TBD2%) required to maintain a Class A fire suppressed is presently not know. In the case of halon 1301, the ration of TBD2/TBD1 is 0.6 and this ratio may be assumed for the halocarbons. Test data on the performance of halocarbons for the deep seated Class A fire threat presently doe not exist. weight and volume equivalent data of table 1 may be used to estimate the agent requirements for equivalent halon 1301 performance. From available data, it is apparent that all SNAP approved and NFPA recognized halocarbons will require increased (60%-100%) agent weight and increased agent (60-120%) storage volume compared to present halon 1301 systems.

Halocarbon systems require pressurized storage bottles. The suggested fill densities and storage pressures are listed in table 1. The halocarbon have low freezing point and low temperature protection of the agent would not be required. However, at higher temperatures, greater than 70°F, The bottle internal pressures would increase and bottles capable of withstanding pressures substantially greater than storage pressure, indicated in table 1, would be required. Several

investigators have conducted studies on the effect of agent discharge time on fire (Class B) suppression effectiveness and products of combustion. Standard 2001 "Alternative Protection Options to halon" of the National Fire Protection Association (NFPA, 1, Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101), recommends a discharge time of 10 seconds or less or otherwise required by the authority having jurisdiction. It is reasonable to assume that a fast discharge time would be required. This would cause increase in compartment internal pressure and means to prevent cargo compartment over-pressurization may be required.

The conceptual system would lend itself for integration with the existing (smoke, ionization) fire detection systems and operation according to the current crew procedures. Like present halon system, the agent will discharge on crew command. Halocarbons are clean agents and no compartment clean up will be required. However, maintenance (bottle replacement and system checkout) of the fire suppression system would be necessary after each use. Agent discharge will reduce cargo compartment oxygen partial pressure, the decrease will be a function of cargo compartment volumetric loading and the compartment altitude at discharge. Based on past experience with halon 1301 systems, it is reasonable to assume that asphyxiation of animals may occur in a heavily loaded (volumetric) cargo compartment. Since, greater halocarbon agent volume (possible exception Trifluoroiodomethane) will be required for equivalent fire suppression capability it is reasonable to conclude that halocarbons would cause greater reduction in oxygen partial pressure. [Note, there is some concern on the Ozone Depleting Potential (0.001) and toxicity of Trifluoroiodomethane. It has been proposed acceptable by US EPA for protection of non-occupied areas subject to public comment. At present, it is not recognized by NFPA in Standard 2001 and its acceptability status in other countries is presently not known.]

Halocarbon systems will be a total flood type. Agent will migrate to all parts of the cargo compartment and leak through available leakage paths. Migration of the agent to compartments occupied by crew and passengers and to equipment located outside the cargo compartment would depend on the integrity of the compartment liner. Means to exclude hazardous quantities of smoke, flames, or extinguishing agent, from any compartment occupied by the crew or passengers is a FAR/JAR 25.857 requirement and it is reasonable to assume that agent migration form a maintained compartment will be a minimum.

Halocarbons (exceptions HFC-125 and FIC-1311) are non-toxic at design concentration levels, (see LOAEL and NOAEL values table 1). However, since the systems are designed based on empty cargo compartments, higher concentrations will result when the compartment is loaded. Note, animal asphyxiation referred to above will probably occur due to the reduction in oxygen partial pressure (Dalton's Law of Partial Pressures) caused by the agent mixing with other gases in the compartment rather than agent toxicity.

The halocarbon system would normally be pressurized. It will be a two phase (halocarbon and inert gas) system. The system maintenance requirements can be reasonably assumed to be the same as the present halon 1301 system and of similar skill level. Periodic pressure test of the bottles would be required.

Particulate Aerosols

Pyrotechnically Generated Aerosols, PGA, has been approved under SNAP for total flooding of unoccupied areas. [NFPA has no Technical Committee or Standard on this technology. A new project on "Fine Aerosol Technology" was authorized on April 13, 1995 by NFPA Standards Council]. Task Group 6 determined the aerosol technology as proprietary or ill defined.

A Class of agents known as EMAA (Encapsulated Micron Aerosol Agent) on activation ignites and creates an aerosol that contains about 40% solid particles (size less than 1 micron) of salts like Potassium Chloride, Potassium Carbonate, etc. The remaining 60% of the emissions are gaseous combustion products such as carbon dioxide, nitrogen, water vapor, oxygen and traces of hydrocarbons. This class of agents provides total flood capabilities. Some studies indicate that on a weight basis, the agents are fire five times more efficient than halocarbon extinguishing systems on Class B fires. Little is known of the capability of this agent to suppress Class A (exposed and deep seated) fires.

Figure 3 shows a conceptual particulate aerosol system. The system consists of agent container(s) with means for agent generation/expulsion. It is reasonable to assume that the system would consist of multiple canisters located along the length of the cargo compartments and with electrical to activate agent release. (The agent/canister/activation means can be reasonably assumed to be similar to chemical oxygen).

The conceptual system would lend itself for integration with the existing (smoke, ionization) fire detection systems and operation according to the present crew procedures. The system operating logic is shown on figure 3. When fire alarm, is annunciated in either the forward or aft compartment, the pilot will arm the corresponding canister(s) activation system by pushing the appropriate compartment arm switch. This action would reconfigure the air-conditioning/ventilation system and illuminate the ARMED legend on the switch plate. (These functions can also be caused to occur automatically on detection of fire) Pressing the discharge switch would create agent aerosol. On discharge of agent (detected by canister temperature rise or other means) the legend DISCH will illuminate. Maintenance (canister replacement and system checkout) of the fire suppression system and clean up of the cargo compartment would be necessary after discharge. Combustion gases generated will reduce cargo compartment oxygen partial pressure. The reduction in oxygen partial pressure will be a function of cargo compartment volumetric loading and the compartment altitude at discharge. Presently, it is not known how much reduction in oxygen partial pressure would typically result with this class of agents. The effect of environment, heavily laden with micron size chemical particles, on the respiratory system of animals is also not known. In all probability it would be deleterious.

Particulate aerosol will be a total flood system. Agent will migrate to all parts of the cargo compartment. Migration of the agent to compartments occupied by crew and passengers and to equipment located outside the cargo compartment would depend on the integration of the compartment liner. Means to exclude hazardous quantities of smoke, flames, or extinguishing agent, from any compartment occupied by the crew or passengers is a FAR/JAR 25.857 requirement and it is reasonable to assume migration from a maintained compartment will be a

minimum. The agent will settle in various areas of the cargo compartment (bilge area, insulation blankets, etc.).

Little is known about the toxicity of this class of agent. They have been approved under SNAP for total flooding of unoccupied areas. Cargo compartments often have animals and it is reasonable to assume that environment laden with microscopic chemical particles would not be in the best interest of animals.

The particulate system requires no pressurized source. It is similar to a chemical oxygen system and it can be assumed that it will require essentially similar scheduled maintenance. It should be noted that these systems are exothermic.

High Expansion Foam

According to the Task Group 6 report, high expansion foam systems are uncommon but can be used for total flooding of a protected space, particularly where a Class A fire may be difficult to access for fire fighting. The conceptual high expansion "total flood" system would be similar to the water based system (without eutectic valves). The system would include the foaming agent and foaming equipment. The system would lend itself for integration with the current fire detection systems and operation by current crew procedures.

It is reasonable to assume that this type of system would be relatively more complex than a water-based system and would require substantial clean-up effort.

Questionnaire

A questionnaire form consisting of four questions is attached for your use. Please use the form to submit your input. Additional sheets may be used to provide other information. The form should be returned by 12 July, 1995, by either fax or mail.

QUESTIONNAIRE

USER PREFERRED AGENT FOR CARGO COMPARTMENTS

This questionnaire must be returned by July 12, 1995

Name: ____________________ Company: ____________________
Tel: ____________________ FAX: ____________________

A. Four agent groups (water and water-based, halocarbons, particulate aerosols and high expansion foams) have been identified for cargo compartment fire suppression. Please list the groups in order of preference.

- *No preference --- (Please skip question B, C, and D)*

Agent Group	Preference (0-undesired, 10=most desired)
1.	
2.	
3.	
4.	

B. Please (I) identify the agent (or agents) that you prefer and (ii) tell us your reasons*.

C. Please (I) list the agent (or agents) that you would not use and (ii) tell us your reasons*.

D. Will you use an agent not recommended for use in areas normally occupied by humans? (i.e., an agent that may create an inhospitable environment for humans).

Yes _____ No_____

E. Other comments/suggestions*.

* Use additional sheets if necessary

F. Please return this questionnaire by 12 July 1995 to A. Gupta. FAX 206-237-5444, or Mailing address: A. Gupta, M/S 6H-TR, Boeing Commercial Airplane Group, P.O. Box 3707, Seattle, WA 98124 (USA)

TABLE A-1. SIGNIFICANT CHARACTERISTICS OF COMMERCIALIZED TOTAL FLOOD HALOCARBON AGENTS.
(Data Extracted from DOT/FAA/CT-95/9 and NFPA Standard 2001)

Agent	Chemical Name	Trade Name	GWP[a]	Atmospheric Life time, years	SNAP[b] approval	NFPA[c]
HFC-23	Trifluoromethane	DuPont "FE-13"	9000	280	acceptable	yes
HFC-125	Pentafluoroethane	DuPont "FE-25"	3400	41	acceptable	yes
HFC-227EA	Heptafluoropropane	Great Lakes "FM-200"	2050	31	acceptable	yes
HFC-236fa	Hexafluoropropane	DuPont "FE-36"	+	+	+	
FC-218	Perfluoropropane	3M "CEA-308"	6100	3200	acceptable	
FC-3-1-10	Perfluorobutane	3M "CEA-410"	5500	2600	acceptable	yes
FIC-1311	Trifluoroidomethane	Pacific Scientific Triodide W. Florida Ordnance Iodoguard		<1 day	acceptable*	

[a]Based on 100-year horizon, relative to CO_2 +Data not available
[b]Significant New Alternatives Policy (SNAP)
[c]National Fire Protection Association (NFPA) Standard 2001, "Alternative Protection Options to Halon"
*Proposed acceptable for protection of non-occupied areas subject to public comment. Also known by Trade name Iodoguard

Agent	NOAEL[d] %	LOAEL[e] %	% Design[f] concentr.(%)	Weight[g] equiv.	Volume[g] equiv.	Fill density (lb/ft^3)	Storage press (psig)	Freezing Point (°F)
HFC-23								
HFC-125								
HFC-227EA								
HFC-236fa								
FC-218								
FC-3-1-10								
FIC-1311								

[d]No Observed Adverse Effect Level
[e]Lowest Observed Adverse Effect Level
[f]Manufacturer (HFC-236fa, FC-218) and Federal Register (HFS-23, HFC-125, HFC-227ea, FC-3-1-10) data
[g]Calculated from data in NFPA Standard 2001. Values in parentheses taken from SNAP listing.
+Data not available

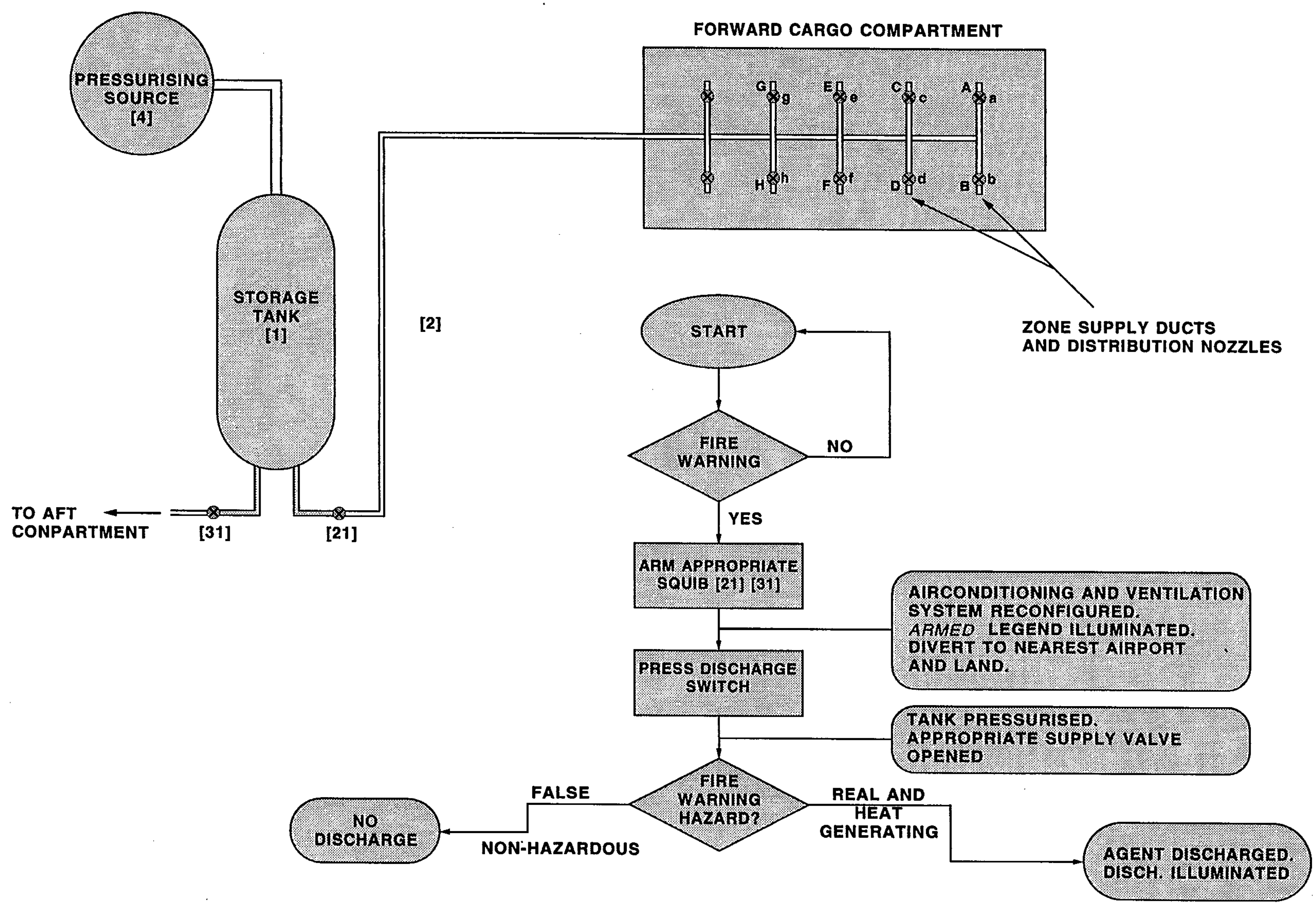

FIGURE A-1. WATER AND WATER BASED FIRE SUPPRESSION SYSTEM (CONCEPTUAL)

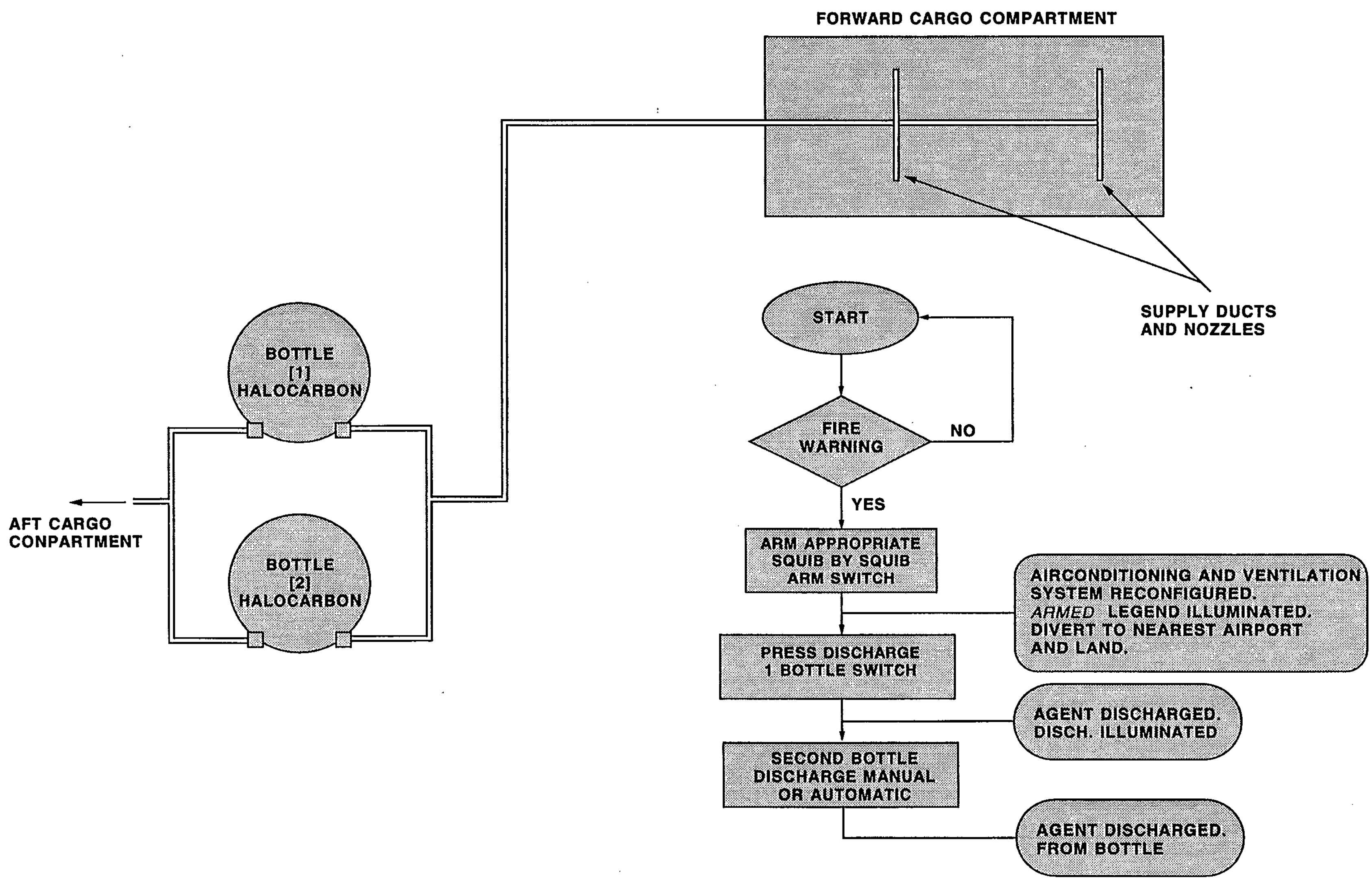

FIGURE A-2. HALOCARBON AND HALOCARBON BLEND SYSTEM (CONCEPTUAL)

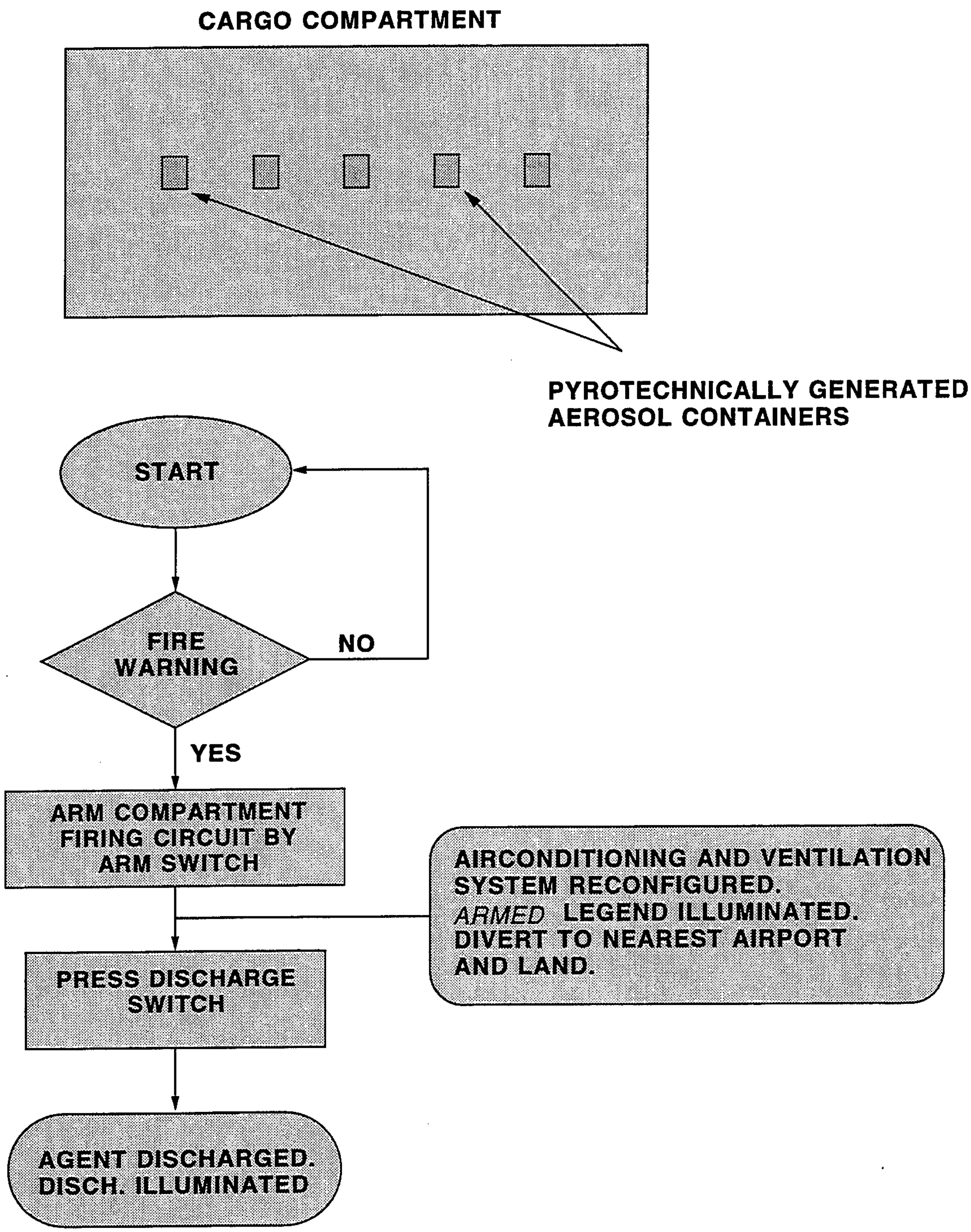

FIGURE A-3. PARTICULATE AEROSOL SYSTEM (CONCEPTUAL)

APPENDIX B—ORGANIZATIONS RECEIVING IHRWG SURVEY

Aer Lingus PLC
Aeroflot Airlines
Aeroflot Cargo (USSR)
Aerospatiale
AIA
Air 2000 LTD
Air Afrique
Air Canada
Air China
Air Creebec Inc.
Air Espana S.A.
Air Europa
Air France
Air India
Air Inter
Air Lanka
Air Macau
Air Transat
Airbus Industrie
Akdeniz Airline
Alaska Airlines
Alitalia S.P.A.
All Nippon Airways
ALM Antillean Airlines
Aloha Airlines
America West Airlines
American Airlines
American Trans Air
Ansett
Asiana Airlines
ATA
Austrian Airlines
Boeing
British Airways
British Cargo Air Lines (UK)
Canadian Airlines
Cargo Lux Airlines (Luxembourg)
Cathay Pacific
China Airlines
China Eastern Airlines
China Northwest Airlines
Continental Airlines
Delta Airlines
Deutsche BA
Douglas Aircraft
Egyptair
El Al Israel Airlines
European Airlines
EVA Airways (Taiwan)
Federal Express
Finnair
Fokker Aircraft B.V.
Garuda Indonesia
Gulf Air
Hapag Lloyd Flugge
Hawaiian Airlines
IATA
Iberia Airlines
ICAO
ILFC
Indian Airlines
Japan Airlines
Kenya Airways
KLM
Korean Airlines
Kuwait Airways
Lockheed Martin
LTU
Lufthansa
Malaysia
Martinair
Mexicana
Midway
Northwest
NW Territorial Airways
Olympic Airways
Pakistan International
Philippine Airlines
Qantas Airways
Raytheon Aircraft (Beech)
Sabena
Saudi Arabian Airlines
Scandinavian Airlines
Singapore Airlines
South African Airways
Southwest Airlines
Swissair
TAP Air Portugal
Tarom S.A.
Thai Airways Inter
Trans World Airlines
Transasia Airways
Tunis Air
United Airlines
United Arab Emirates
USAir
Uzbekistan Airways
Varig
VASP Airlines
Vietnam Airlines
Virgin Atlantic Airways
World Airways